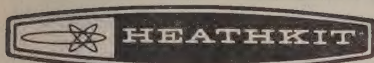


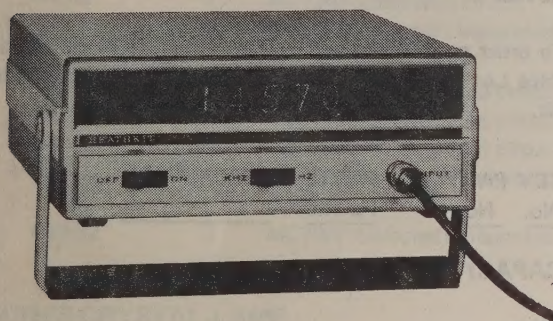
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Operation
of the



FREQUENCY COUNTER

MODEL IB-101



HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

RECEIVED

NOV 30 1979

VLI

INTRODUCTION

The Model IB-101 Heathkit Frequency Counter is a compact, lightweight, and rugged digital frequency counter. The basic functions and uses of this Instrument are like those found in other high quality frequency counters.

Many features make the Counter convenient and easy to operate. Five cold-cathode display tubes, an overrange lamp, and two range indicator lamps provide an easy-to-read "readout." The "readout" accuracy is assured by the modern digital techniques and a crystal-controlled "clock."

A high impedance (MOSFET) input circuit presents minimum loading to the circuit under test, and the automatic level triggering feature provides simple "hands-off" operation. The Counter's two regulated power supplies can be operated from either a 105 to 125 or a 210 to 250 volt 50/60 Hz ac power source.

Lightweight and reliable plug-in integrated circuits minimize and simplify maintenance. The detachable test cable and line cord and the three-detent position bail-handle make the Counter completely portable. The unique bail-handle can be used to position the Counter at a desirable viewing angle.

PARTS LIST

Check each part against the following parts list. The key numbers correspond to the numbers on the Parts Pictorial (fold-out from Page 7).

To order replacement parts, refer to the "Replacement Parts Price List" and use the Parts Order Form furnished with this kit.

KEY PART No.	KEY PART No.	PARTS Per Kit	DESCRIPTION
RESISTORS			
1/2-Watt, 5%			
1	1-151	1	330 Ω (orange-orange-brown)
	1-157	2	470 Ω (yellow-violet-brown)
	1-52	1	680 Ω (blue-gray-brown)
	1-81	1	1500 Ω (brown-green-red)
	1-150	2	3000 Ω (orange-black-red)
	1-122	1	3300 Ω (orange-orange-red)
	1-43	1	4700 Ω (yellow-violet-red)
	1-51	1	6800 Ω (blue-gray-red)
	1-105	8	10 k Ω (brown-black-orange)
	1-115	3	47 k Ω (yellow-violet-orange)
	1-50	1	68 k Ω (blue-gray-orange)
	1-104	1	100 k Ω (brown-black-yellow)
	1-101	2	1M Ω (brown-black-green)

Other Resistors-Control

1-9	3	1000 Ω , 1/2-watt, 10% (brown-black-red) resistor
2	2-219	21.62 Ω , 1% resistor
3	3-2-5	10 k Ω , 5-watt resistor
4	10-171	500 Ω control

KEY PART No.	KEY PART No.	PARTS Per Kit	DESCRIPTION
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CAPACITORS

Disc

5	21-24	1	800 pF
	21-52	1	.002 μ F
	21-47	1	.01 μ F
	21-48	4	.05 μ F

Mica

6	20-101	1	47 pF
	20-102	3	100 pF
	20-107	1	680 pF

Electrolytic

7	25-94	1	10 μ F
8	25-128	1	100 μ F
9	25-230	2	2000 μ F

Other Capacitors

10	31-36	1	8-50 pF trimmer
11	21-41	1	14 pF ceramic (violet-brown-yellow-black-green)



KEY PART	PARTS	DESCRIPTION
No. No.	Per Kit	

TUBE-TRANSISTORS-INTEGRATED CIRCUITS

12	411-264	5	B5859S display tube
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NOTE: Transistors and integrated circuits are marked for identification in one of the following four ways:

1. Part number.
2. Transistor or integrated circuit type number.
3. Part number and type number.
4. Part number with a type other than the one listed.

13	417-118	2	2N3393 transistor
	417-201	3	X29A829 transistor
14	417-173	1	NPN transistor
15	417-240	1	40673 transistor
16	417-175	1	TA2911 transistor
17	443-8	1	MC724P integrated circuit
IC-24	443-14	1	MC789P (selected) integrated circuit
	443-28	10	CμL995879 integrated circuit
	443-29	5	CμL995979 integrated circuit
	443-30	5	CμL996079 integrated circuit
IC-21	443-31	1	MC726P (selected) integrated circuit
	443-32	3	MC790P (selected) integrated circuit

DIODES-CRYSTAL-LAMP

18	56-26	1	Crystal diode, 1N191 (brown-white-brown)
	56-55	1	36 V zener diode, VR-36A
	56-59	1	4.7 V zener diode, 1N750A (violet-green-brown)
	57-27	3	Silicon diode, 1N2071
19	404-414	1	1 MHz crystal
20	412-49	3	Neon lamp

SWITCHES-SOCKETS-ADAPTER-CONNECTORS

21	60-40	1	3PDT switch
22	60-45	1	SPST switch
23	432-76	1	AC power socket
24	434-201	5	Tube socket
25	432-27	1	Plug adapter
26	432-59	1	BNC connector (with hardware)
27	432-144	393	Integrated circuit (IC) connector

KEY PART	PARTS	DESCRIPTION
No. No.	Per Kit	

LINE CORD-WIRE-CABLE

89-30	1	3-wire line cord
340-11	1	Bare wire
344-50	1	Black wire
344-51	1	Brown wire
344-21	1	Large red wire
344-52	1	Small red wire
344-53	1	Orange wire
344-54	1	Yellow wire
344-55	1	Green wire
344-56	1	Blue wire
344-57	1	Violet wire
344-58	1	Gray wire
134-237	1	Cable assembly (with connector)

HARDWARE

#4 Hardware

28	250-3	4	4-40 x 3/16" screw
29	250-52	11	4-40 x 1/4" screw
30	252-15	7	4-40 nut
31	254-9	7	#4 lockwasher

#6 Hardware

32	250-89	10	6-32 x 3/8" screw
33	250-434	8	6-32 x 3/8" flat head screw
34	250-535	2	6-32 x 1/4" screw
35	252-3	14	6-32 nut
36	254-1	16	#6 lockwasher
37	259-1	1	#6 solder lug
38	255-103	1	6-32 x 5/16" threaded spacer

Other Hardware

39	253-75	3	3/8" flat washer
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METAL PARTS

40	90-505-1	2	Cabinet shell
41	200-592	1	Chassis
42	100-1039	1	Front panel
43	203-747-1	1	Rear panel
44	203-748	1	Left panel
45	203-749	1	Right panel
46	205-780	2	Cabinet trim plate
47	211-51	1	Handle
48	258-106	1	Flat spring
49	266-194	1	Handle detent
50	205-141	2	Tool plate

KEY PART	PARTS	DESCRIPTION
No. No.	Per Kit	

MISCELLANEOUS

51	40-581	2	620 μ H coil
	54-260	1	Power transformer
52	73-34	2	Rubber insulator
	85-576-1	1	Circuit board
53	205-778	1	1/8" x 1" metal strip
54	211-52	1	Plastic handle-grip
55	214-124	2	Lamp housing
56	260-16	2	Alligator clip
57	261-29	4	Plastic foot
58	262-13	1	Pin
59	390-331	1	Control label

KEY PART	PARTS	DESCRIPTION
No. No.	Per Kit	

Miscellaneous (cont'd.)

60	75-156	1	Light shield
61	390-357	1	"Heathkit" label
	421-33	1	1/4-ampere, slow-blow fuse
62	422-1	1	Fuseholder
63	431-38	2	3-lug terminal strip
64	490-5	1	Nut starter
	391-34	1	Blue and white label
	597-308	1	Kit Builders Guide
	597-260	1	Parts Order Form
		1	Manual (See front cover for part number.)
			Solder

ASSEMBLY NOTES

Before starting to assemble this kit, be sure you have read the wiring, soldering, and step-by-step assembly information in the "Kit Builders Guide."

Due to the small foil area around the circuit board holes and the small areas between foils, it will be necessary to use the utmost care to prevent solder bridges between adjacent foil areas. Use only a minimum amount of solder, and do not heat components excessively with the soldering iron. Diodes, transistors, etc., can be damaged if subjected to excessive amounts of heat. Use no larger than a 25-watt soldering iron with a small tip. Allow it to reach operating temperature, and then apply it only long enough to make a good solder connection.

NOTE: If a small wattage, small-tip soldering iron is not available, proceed as follows: Be sure your soldering iron is cool. Then wrap the large bare wire, supplied with this kit, tightly around the soldering iron tip as shown in Figure 1. Allow approximately 1/2" of wire to extend beyond the end of the soldering iron. Cut the wire end to a chisel shape as shown.

Resistors will be called out by their resistance value in Ω , k Ω , or M Ω , and color code. Use 1/2-watt resistors unless directed otherwise.

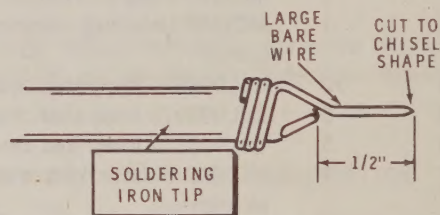


Figure 1

Capacitors will be called out by their capacitance value (in pF or μ F) and type (disc, mica, or electrolytic).

NOTE: The circuit board has foil on both sides of the board. Components will be installed on the screened (side with the component outlines) side, and the leads will be soldered to the foil on the other side. Never make a solder connection on the screened side of the circuit board. Due to the nature of the board, solder may be drawn through a circuit board hole to the screened side. This is normal.

CALIBRATION

- () Turn the Counter on and allow it to warm up for 30 minutes.
- () Locate the 1/8" x 1" metal strip. This is the alignment tool tip. With a pair of pliers, insert the tip into the small end of the nut starter so that it extends 1/8" from the end of the starter as shown in Figure 3. Use this tool for all calibration adjustments.
- () Remove the top cabinet shell.

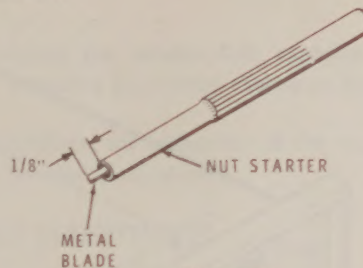


Figure 3

NOTE: The remaining portion of the calibration is divided into two sections: "Without Instruments" and "With Instruments." the "With Instruments" section requires the

use of a frequency counter and/or a frequency generator. Choose one of the two sections and perform only the steps in that section.

Without Instruments

CLOCK

- () Remove the test cable from the counter INPUT connector, if it is not already done.
- () Tune a standard broadcast (AM) receiver to any station.
- () Place the antenna of the receiver near the oscillator crystal in the Counter. See Figure 4.
- () Adjust the variable CAL capacitor for a null (Minimum sound or zero beat) from the receiver.

TIME BASE CLOCK OSCILLATOR ADJUSTMENT TO STATION WWV

Tune a Communications Receiver, using its "AM" Mode, to the highest frequency WWV broadcast station (25, 20, 15, 10 or 5 MHz) that will produce a relatively noise-free signal and constant S meter indication. Attach an insulated wire (not shielded) to the receiver antenna and lay the other end of the wire near the IB-101 oscillator section (IC-25).

When WWV transmits carrier only (no modulation) the 1 MHz clock signal will beat with the clock's multiple WWV signal and the difference frequency will be heard from the receiver. Adjust the IB-101 CAL capacitor for a zero beat in the receiver. Note the reading on S meter of the receiver and continue to adjust this capacitor for the most stable S meter indication and zero beat from the receiver.

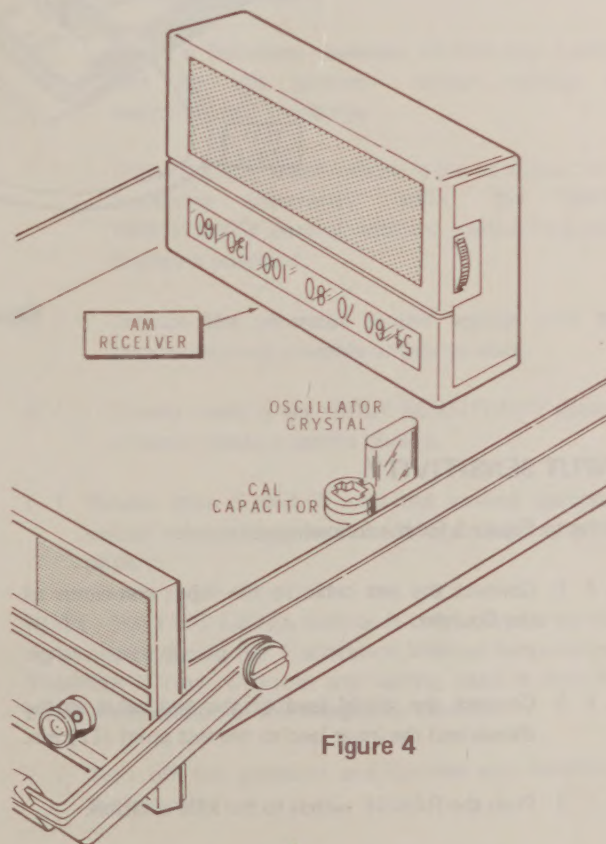


Figure 4

The receiver antenna and/or the IB-101 wire coupling to the receiver may require adjusting to produce a satisfactory S meter indication.

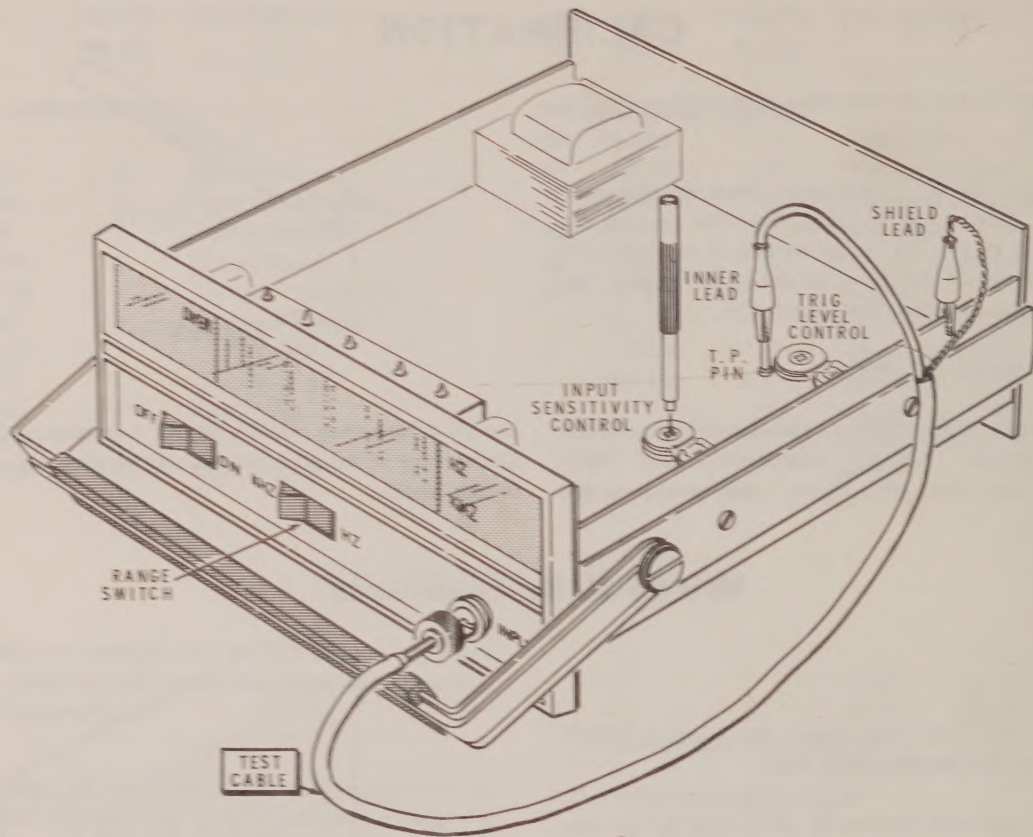


Figure 5

INPUT SENSITIVITY

Refer to Figure 5 for the following steps.

1. () Connect the test cable to the input connector of the Counter.
2. () Connect the shield lead of the test cable to the chassis and the inner lead to the test point (TP) pin.
3. () Push the RANGE switch to the kHz position.
4. () If a reading of 10 kHz is not present, adjust the INPUT SENSITIVITY control until this reading appears.
5. () Turn the TRIG LEVEL control very slowly in a clockwise direction until the 10 kHz reading just disappears or changes to a lower number.
6. () Readjust the INPUT SENSITIVITY control very slowly until the 10 kHz reading is again obtained.
- () Repeat steps 5 and 6 until the TRIG LEVEL control is turned as far clockwise as possible and the counter still displays 10 kHz.
- () Turn the Counter off and disconnect the test cable leads.
- () Replace the top cabinet-shell.

This completes the calibration of your Frequency Counter.

With Instruments

CLOCK

Determine which of the following clock calibration methods you will use. Then complete the steps under the appropriate heading.

Calibration With a Frequency Counter and Signal Generator.

Equipment Required:

1. Frequency counter.
 2. Signal generator capable of 15 MHz, 250 mV output.
- () Connect the test leads of the above frequency counter to the output terminals of the signal generator. See Figure 6.
- () Also connect the test leads of the IB-101 Frequency Counter to the output terminals of the signal generator.
- () Set the signal generator to 15 MHz at 250 mV output.
- () Adjust the Model IB-101 variable CAL capacitor until the IB-101 indicates exactly the same frequency as the other frequency counter.
- () Disconnect the test leads.

The accuracy of this IB-101 counter is now dependent on the accuracy of the other frequency counter.

This completes the calibration of the clock. Proceed to the Input Sensitivity adjustment.

Calibration With a Known Frequency

NOTE: When using this method, it is essential that the known frequency (10 kHz or greater - 15 MHz is ideal) be stable. The accuracy of this type of calibration is dependent on the accuracy in percentage of the known frequency.

- () Connect a known frequency to the test cable of the Counter.
- () Push the RANGE switch to the Hz position.

- () Adjust the variable CAL capacitor until the known frequency is indicated exactly on the Counter.

This completes the calibration of the clock. Proceed to the Input Sensitivity adjustment.

INPUT SENSITIVITY

EQUIPMENT REQUIRED:

10 kHz - 1 MHz generator with an output of 50 mV rms to 1 volt rms continuously variable.

1. () Connect the test cable to the input connector of the Counter. See Figure 7.
 2. () Connect the Counter test cable to the output frequency generator.
 3. () Select a frequency (between 10 kHz and 1 MHz) and set the generator output voltage to approximately 1 volt rms.
 4. () If the Counter is not indicating the frequency, or is indicating incorrectly, adjust the INPUT SENSITIVITY control until the correct frequency display is obtained.
 5. () Reduce the generator output voltage until the display becomes unstable or goes to zero.
 6. () Slowly readjust the INPUT SENSITIVITY control to again obtain a correct display.
- () Repeat steps 5 and 6 until the smallest generator output voltage is reached that still produces a correct display.

NOTE: The TRIG LEVEL control is only used as a variable signal source during the "Calibration Without instruments." Therefore it may remain at any setting, since it does not affect the operation of this Frequency Counter.

- () Turn off the generator and Counter and disconnect the test cable.
- () Replace the top cabinet shell.

This completes the calibration of your Frequency Counter.

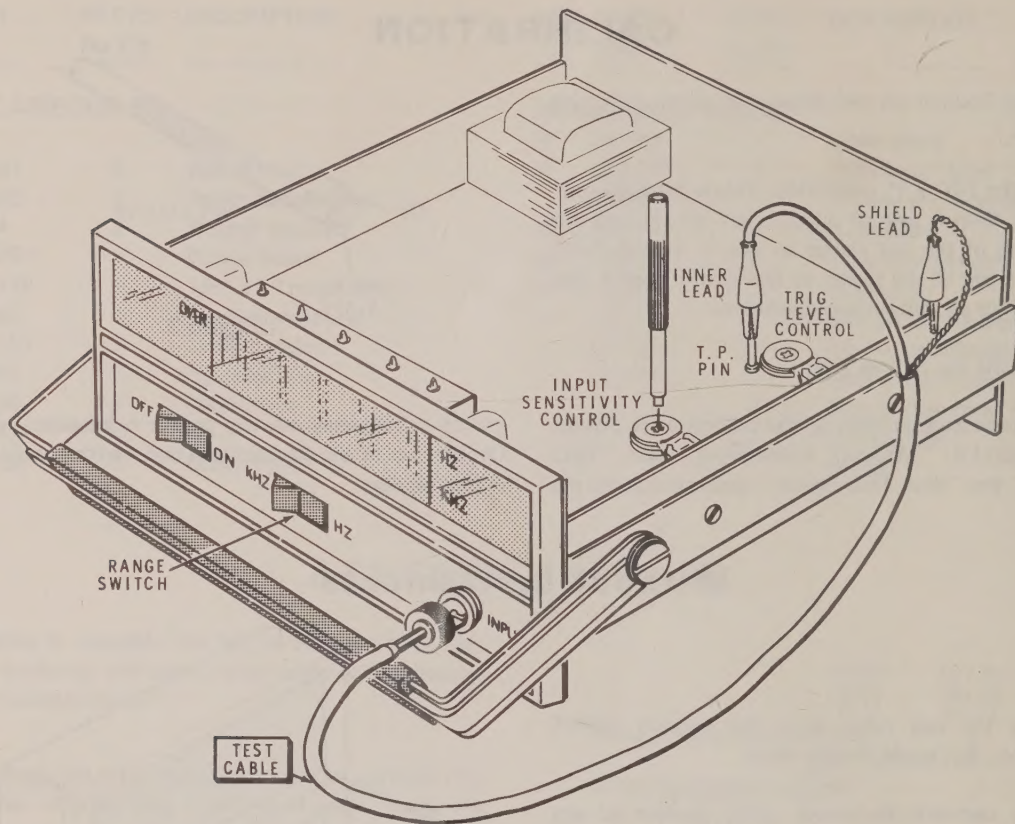


Figure 5

INPUT SENSITIVITY

Refer to Figure 5 for the following steps.

1. () Connect the test cable to the input connector of the Counter.
2. () Connect the shield lead of the test cable to the chassis and the inner lead to the test point (TP) pin.
3. () Push the RANGE switch to the kHz position.
4. () If a reading of 10 kHz is not present, adjust the INPUT SENSITIVITY control until this reading appears.
5. () Turn the TRIG LEVEL control very slowly in a clockwise direction until the 10 kHz reading just disappears or changes to a lower number.
6. () Readjust the INPUT SENSITIVITY control very slowly until the 10 kHz reading is again obtained.
- () Repeat steps 5 and 6 until the TRIG LEVEL control is turned as far clockwise as possible and the counter still displays 10 kHz.
- () Turn the Counter off and disconnect the test cable leads.
- () Replace the top cabinet-shell.

This completes the calibration of your Frequency Counter.

With Instruments

CLOCK

Determine which of the following clock calibration methods you will use. Then complete the steps under the appropriate heading.

Calibration With a Frequency Counter and Signal Generator.

Equipment Required:

1. Frequency counter.
 2. Signal generator capable of 15 MHz, 250 mV output.
- () Connect the test leads of the above frequency counter to the output terminals of the signal generator. See Figure 6.
- () Also connect the test leads of the IB-101 Frequency Counter to the output terminals of the signal generator.
- () Set the signal generator to 15 MHz at 250 mV output.
- () Adjust the Model IB-101 variable CAL capacitor until the IB-101 indicates exactly the same frequency as the other frequency counter.
- () Disconnect the test leads.

The accuracy of this IB-101 counter is now dependent on the accuracy of the other frequency counter.

This completes the calibration of the clock. Proceed to the Input Sensitivity adjustment.

Calibration With a Known Frequency

NOTE: When using this method, it is essential that the known frequency (10 kHz or greater - 15 MHz is ideal) be stable. The accuracy of this type of calibration is dependent on the accuracy in percentage of the known frequency.

- () Connect a known frequency to the test cable of the Counter.
- () Push the RANGE switch to the Hz position.

- () Adjust the variable CAL capacitor until the known frequency is indicated exactly on the Counter.

This completes the calibration of the clock. Proceed to the Input Sensitivity adjustment.

INPUT SENSITIVITY

EQUIPMENT REQUIRED:

10 kHz — 1 MHz generator with an output of 50 mV rms to 1 volt rms continuously variable.

1. () Connect the test cable to the input connector of the Counter. See Figure 7.
 2. () Connect the Counter test cable to the output frequency generator.
 3. () Select a frequency (between 10 kHz and 1 MHz) and set the generator output voltage to approximately 1 volt rms.
 4. () If the Counter is not indicating the frequency, or is indicating incorrectly, adjust the INPUT SENSITIVITY control until the correct frequency display is obtained.
 5. () Reduce the generator output voltage until the display becomes unstable or goes to zero.
 6. () Slowly readjust the INPUT SENSITIVITY control to again obtain a correct display.
- () Repeat steps 5 and 6 until the smallest generator output voltage is reached that still produces a correct display.

NOTE: The TRIG LEVEL control is only used as a variable signal source during the "Calibration Without instruments." Therefore it may remain at any setting, since it does not affect the operation of this Frequency Counter.

- () Turn off the generator and Counter and disconnect the test cable.
- () Replace the top cabinet shell.

This completes the calibration of your Frequency Counter.

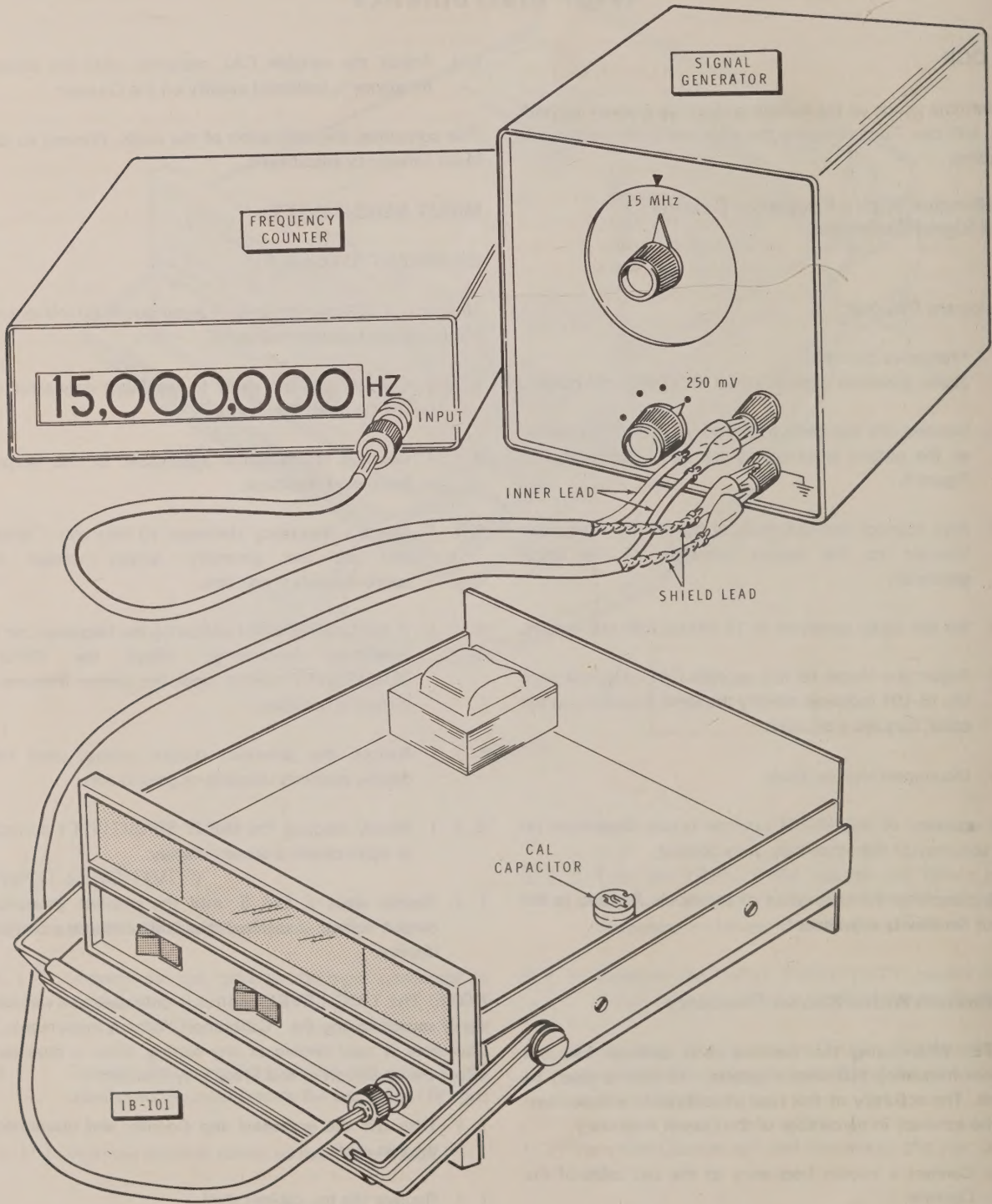


Figure 6

OPERATION

Figure 8 gives a brief description of each control function.

COUNTING 5-DIGIT FREQUENCIES OR LESS

To count a frequency of five digits or less, push the RANGE switch to the Hz position and wait 4 seconds. Within 2 seconds a display will appear. However, this display is inaccurate as it was probably counted in less than one counting period. The second display, which will appear two seconds after the first, will be counted over a full counting period and will therefore be accurate.

COUNTING 6-DIGIT FREQUENCIES AND GREATER

To count a frequency of 11,381,367 Hz for example, push the RANGE switch to the kHz position. (The 4-second wait

is not necessary as the frequency display is updated each 1/10 second in this range.) Record the display mentally or on paper; it will read 11,381 kHz. Push the RANGE switch to the Hz position and record this reading; it will read 81,367. (The OVER lamp will turn on in this example as the frequency will be 3 digits larger than can be displayed.) Putting the two readings together, the frequency is read as 11,381,367 Hz.

± 1 COUNT

The clock of a digital counter is not synchronized with the incoming signal. That is, the 1-second standard in the Counter is started randomly with respect to the input signal. This makes it necessary to wait for 4 seconds when the RANGE switch is in the Hz position and causes a ± 1 count error as shown in Figure 9. If the clock starts as clock A, the counter will count 10 pulses in that second. However, if the

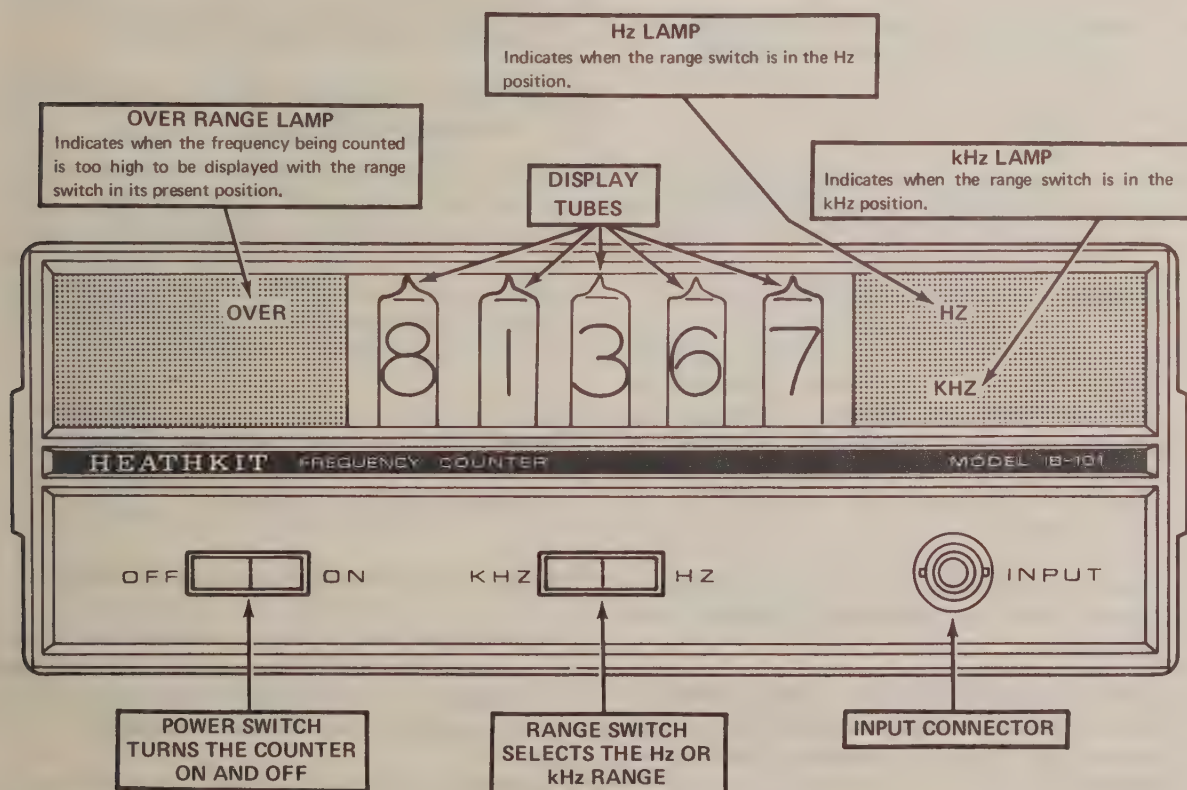


Figure 8

clock starts as clock B, the counter will count 11 pulses in that second. Hence, digital counters have an inherent error of ± 1 in the least significant digit. The range does not matter. The right-hand digit is always ± 1 count.

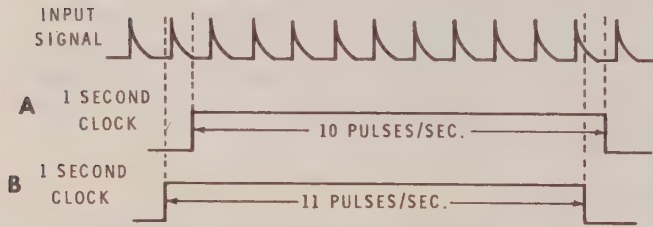


Figure 9

CAUTION

DC BLOCKING

If the input signal is superimposed on a dc level, connect an appropriate capacitor in series with the test cable. This will block the dc so the signal frequency can be counted.

MAXIMUM AC INPUT

Refer to the chart on Page 40 which represents the input voltages permissible at given frequencies. Note that the maximum input voltage is determined by frequency. Exceeding these levels will destroy the input stage (FET Q1).

IN CASE OF DIFFICULTY

Begin your search for any trouble that occurs after assembly by carefully following the steps listed in the Visual Tests section. After visual tests are completed, refer to the Troubleshooting Chart.

NOTE: Refer to the Circuit Board X-Ray View on Page 50 for the physical location of parts on the circuit board.

VISUAL TEST

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as it is checked. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something consistently overlooked by the kit builder.
2. About 90% of the kits that are returned to the Heath Company for repair do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure that they are soldered as described in the "Soldering" section of the "Kit Builders Guide."
3. Check to be sure that all transistors are in their proper locations. Make sure each lead is connected to the proper point.
4. Check that each of the IC pins are properly installed in their connectors, and not bent out or under the IC. Also be sure the IC's are installed in their correct positions.
5. Check the values of the parts. Be sure in each step that the proper part has been wired into the circuit, as shown in the Pictorial diagrams. It would be easy, for

example, to install a 680 Ω (blue-gray-brown) resistor where a 6800 Ω (blue-gray-red) resistor should have been installed.

6. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the wiring.
7. A review of the Circuit Description may also help you determine where the trouble is.

If the trouble is still not located after the visual tests are completed, and a voltmeter is available, check voltage readings against those shown on the Schematic Diagram (fold-out from Page 55). Read the "Precautions for Troubleshooting" before making any measurements. NOTE: All voltage readings were taken with a high impedance voltmeter. Voltages may vary as much as $\pm 20\%$.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Service" section and Warranty of the "Kit Builders Guide" and to the "Factory Repair Service" information on Page 39 of this Manual.

PRECAUTIONS FOR TROUBLESHOOTING

1. Be cautious when testing IC and transistor circuits. Although they have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage or current than tubes.
2. Be sure you do not short any terminals to ground when making voltage measurements. If the probe should slip, for example, and short out a bias or supply point, it is very likely to cause damage to one or more IC's, transistors, or diodes.

Troubleshooting Chart

The chart lists the condition and the possible cause of the malfunction. If a particular part or parts are mentioned (transistor Q2 for example, or resistor R6) as a possible cause, check these parts to see if they are incorrectly installed or wired incorrectly. Also check to see if an improper part was installed at that location. It is also

possible, on rare occasions, for a part to be faulty.

NOTE: Many integrated circuits have identical devices used in the Counter. A faulty IC can be discovered by interchanging it with a good one.

CONDITION	POSSIBLE CAUSE
One readout does not reset to zero with the input shorted.	1. Check associated decade counter, buffer storage, and decoder IC's.
Readouts will not reset to zero in the Hz or kHz range.	1. IC24. 2. Transistor Q2. 3. IC1, 2, or 3. 4. IC25. 5. Crystal Y1.
Unit functions normal in kHz range but not in Hz range.	1. IC6.
Display tubes will not light.	1. +170-volt supply. 2. Diode D3. 3. IC's 7, 8, 9, 10, or 11.
One or more display tubes will not light.	1. Diode D3.
One display tube does not indicate correct numeral from known frequency source.	1. Check associated decade counter, buffer storage, and decoder driver IC's.
Unit resets to zero but will not count.	1. Check position of the range (Hz-kHz) switch. 2. Check amplitude of input signal. 3. Transistor Q1. 4. IC24. 5. IC21. 6. DC on input signal.
Overrange lamp does not function or is on continuously.	1. Transistor Q3. 2. IC26. 3. Transistor Q4.
Counting sequence is displayed during gating.	1. Memory transfer line. 2. IC24.
Decimal point does not light.	1. Resistor R20. 2. Interchange tube V1 with another display tube.
Hz-kHz lamps. One or both does not function properly.	1. Switch S102. 2. Resistor R21. 3. Hz and/or kHz lamp.

FACTORY REPAIR SERVICE

You can return your completed kit to the Heath Company Service Department to have it repaired for a minimum service fee. (Kits that have been modified will not be accepted for repair.) If you wish, you can deliver your kit to a nearby Heath Authorized Service Center. These centers are listed in your Heathkit catalog.

To be eligible for replacement parts under the terms of the warranty, equipment returned for factory repair service, or delivered to a Heath Authorized Service Center, must be accompanied by the invoice or the sales slip, or a copy of either. If you send the original invoice or sales slip, it will be returned to you.

If it is not convenient to deliver your kit to a Heath Authorized Service Center, please ship it to the factory at Benton Harbor, Michigan and follow the following shipping instructions:

Prepare a letter in duplicate, containing the following information:

- Your name and return address.
- Date of purchase.
- A brief description of the difficulty.
- The invoice or sales slip, or a copy of either.
- Your authorization to ship the repaired unit back to you C.O.D. for the service and shipping charges, plus the cost of parts not covered by the warranty.

Attach the envelope containing one copy of this letter directly to the unit before packaging, so that we do not overlook this important information. Send the second copy of the letter by separate mail to Heath Company, Attention: Service Department, Benton Harbor, Michigan.

Check the equipment to see that all parts and screws are in place. (Do not include wooden cabinets when shipping receivers, tuners, amplifiers, or TV sets, as these are easily damaged in shipment.) Then, wrap the equipment in heavy paper. Place the equipment in a strong carton, and put at least **THREE INCHES** of resilient packing material (shredded paper, excelsior, etc.) on all sides, between the equipment and the carton. Seal the carton with gummed paper tape, and tie it with a strong cord. Ship it by prepaid express, United Parcel Service, or insured parcel post to:

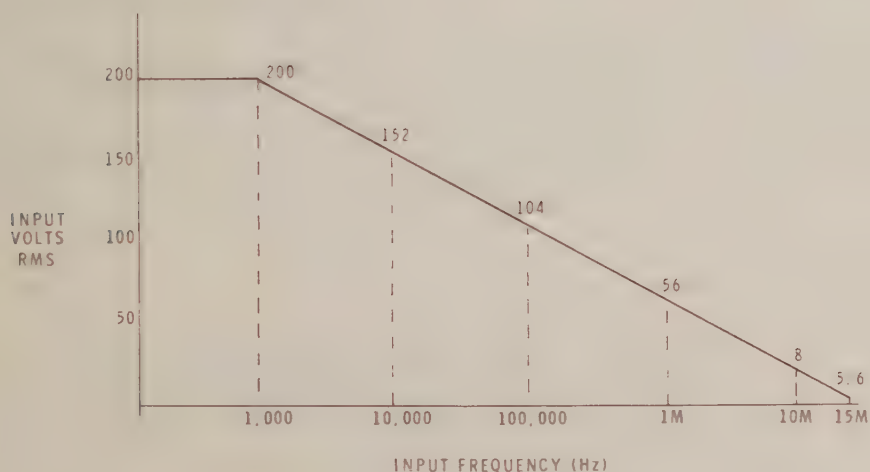
Heath Company
Service Department
Benton Harbor, Michigan 49022

SPECIFICATIONS

Frequency Range	1 Hz to >15 MHz.
Accuracy	± 1 count $\pm$ time base stability.
Gate Times	1 millisecond or 1 second; with automatic reset.

INPUT CHARACTERISTICS

Sensitivity	1 Hz to 1 MHz; <100 millivolt rms. 1 MHz to 15 MHz; <250 millivolt rms after 30 minutes operation.
Trigger Level	Automatic.
Impedance	1 M Ω shunted by <20 pF.
Maximum Input	AC only, 200 volts rms; (dc coupled) 1 Hz to 1 kHz. (Derate 48 volts per frequency decade.)



TIME BASE

Frequency	1 MHz, crystal controlled.
Aging Rate	<1 PPM/Month after 30 days operation.
Ambient Temperature Stability	<±2 parts in 10^7 /degree C. 20 degrees C to 35 degrees C after 30 minutes warmup. ±.002 percent from 0 degrees C to 40 degrees C.

GENERAL

Readout	5 digit plus overrange.
Ambient Temperature Range	Storage: -55 degrees C to 80 degrees C. Operating: 0 degrees to 40 degrees C.
Power Requirements	105-125 or 210-250 Vac, 50/60 Hz, 8 watts.
Cabinet Dimensions	8-1/4" wide x 3-3/8" high x 9" deep. (Dimensions do not include handle.)
Net Weight	4-1/2 lbs.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

CIRCUIT DESCRIPTION

Refer to the Block Diagram (fold-out from Page 36) and Schematic Diagram (fold-out from Page 55) while you read this "Circuit Description."

GENERAL

The input amplifier and Schmitt trigger circuits accept and shape the input signal into a square-wave signal. Decade counters change these sequential input pulses into a binary-coded 8-4-2-1 output and recycle on every tenth input pulse. The four-bits of binary-coded information are then connected to the buffer/storage units which accept and store the count information on command of the transfer signal. The decoder-drivers translate the binary-coded information from the buffer/storage units into decimal form and drive the proper display tube cathodes. Timing signals for gating, transfer, and reset are generated in the clock and divider chain.

INPUT AMPLIFIER

The input amplifier consists of a dual-gate MOSFET. This particular type of device is used because it has a high impedance input which prevents loading of the circuits under test. It is also capable of handling a wide range of input voltages and waveshapes. Internal zener diodes protect this transistor against overload.

SCHMITT TRIGGER

Inverters E and F form a Schmitt trigger circuit. This circuit shapes the input signal so it is suitable for driving the logic circuits that follow. A low frequency input signal is taken from the drain of FET Q1 and attenuated by resistor R5 before reaching inverter F. At high frequencies, the

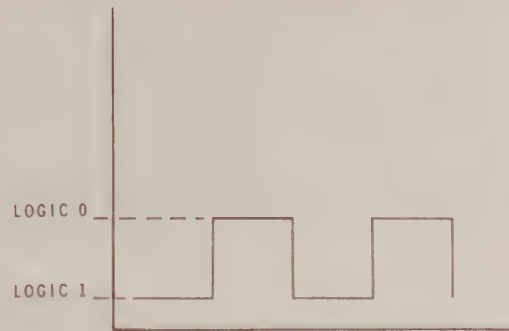


Figure 10

impedance of capacitor C4 decreases, bypassing the signal around resistor R5. The impedance of coil L1 will increase as the input signal frequency increases. This prevents excessive attenuation of the high frequency input signals. The Schmitt trigger circuit is a regenerative bistable circuit which produces a square-wave output each time it is triggered and reset. This square-wave output may be interpreted as logic levels; logic 1 being the negative portion and logic 0 being the positive portion of the square wave as shown in Figure 10. Note that the logic 1 level is negative (low) with respect to the logic 0 level (high). This is called negative logic. Negative logic will be used throughout this "Circuit Description."

The Input Sensitivity control, R7 adjusts the threshold of the Schmitt trigger circuit. The voltage divider, formed by resistors R4, R5, R6, coil L1, and control R7 is adjusted so the voltage at the input of inverter F is just below its turn-on point. This insures that very small input signals can be measured with the Counter.

DECADE COUNTERS

The decade counters change the sequential input pulses from the Schmitt trigger into a binary-coded 8-4-2-1 output. The first decade counter consists of four J-K flip-flops and two NAND gates connected in such a way as to divide-by-ten as well as furnish the required 8-4-2-1 output.

Each of the J-K flip-flops have two complementary outputs Q and $\bar{Q}$ (not Q) which are always at opposite levels. When Q is logic 1, $\bar{Q}$ is logic 0; when Q is logic 0, $\bar{Q}$ is logic 1.

A flip-flop is said to be in its logic 1 state whenever the Q output is logic 1. It is in its logic 0 state whenever the Q output is logic 0.

The C_d (direct clear) input clears or presets the flip-flops to the logic 1 (negative logic) state regardless of any input applied. When a logic 0 level is applied to C_d , the Q output is forced to a logic 1 and $\bar{Q}$ to a logic 0 level.

The logic levels applied to control inputs S and C determine the output levels of Q and $\bar{Q}$ only after an adequate clock (or toggle) pulse is applied to input T . Changes in input level to S and C alone will not produce a change in output levels. A clock pulse applied to input T must be a negative-going pulse (logic 0 to logic 1) with a fast fall time, such as the trailing edge of a square wave. Steady-state logic level and positive-going pulses (logic 1 to logic 0) will not cause the flip-flop to change states.

Figure 11 illustrates the symbol and truth table for a J-K flip-flop. The t_{n+1} column shows the state of the flip-flop coincident with the application of the clock pulse. The term Q_n represents the output state of the flip-flop prior to the application of a clock pulse; while $\bar{Q}_n$ represents the output state opposite that which existed prior to the application of the clock pulse.

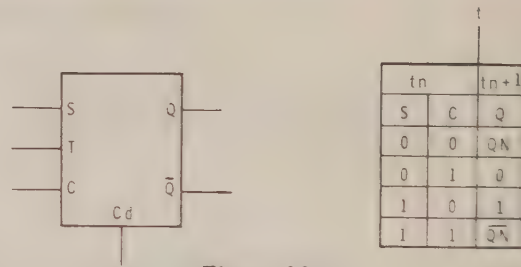


Figure 11

Figure 12 shows the symbol and truth table for a two input NAND gate. A logic 0 (high) is produced at the output only when both inputs are logic 1 (low) at the same time.

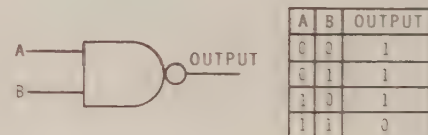


Figure 12

A NAND gate may also be used as an inverter if one input is held at logic 1. See Figure 13. Since the B input is grounded (logic 1), the output will always be at an opposite state from input A . Thus, the output signal is the inverse of the input signal.



Figure 13

Figure 14 illustrates how four flip-flops and two NAND gates are connected to divide-by-ten, their waveform relationships, and a count sequence chart. Assume all four flip-flops to be in a reset state. In this condition, the Q output of each flip-flop will be low or logic 1 (negative logic). The binary-coded 8-4-2-1 output is 0000 (decimal 0).

As long as the S and C inputs are held at logic 0 (high) by the timing circuit, FF1 cannot change states. This timing signal, generated in the master oscillator circuit, allows the input signal to be counted for a predetermined length of time. Input signals are counted and accumulated for 1 ms in the kHz position of the Range switch and for 1 s in the Hz position.

The first negative-going input pulse at time t_1 sets FF1 to its 0 state. Output $\bar{Q}$ is now logic 1 and the 8-4-2-1 output is 0001 (decimal 1).

The second negative-going input pulse at time t_2 sets FF1 to its 1 state. As the Q output of FF1 goes negative, it sets FF2 to its 0 state. The $\bar{Q}$ output of FF2 is now logic 1 and the 8-4-2-1 output is 0010 (decimal 2). Since the Q output of FF4 is coupled to the C input to FF2, FF2 is enabled when FF4 is in its reset state (Q=logic 1). Only when FF4 is in its 0 state will FF2 be inhibited. The Q output of FF1 is also applied to the T input of FF4. Since FF4 is also inhibited (C input high) by gate C, FF4 cannot change states. Only when the $\bar{Q}$ outputs from FF2 and FF3 are logic 1 at the same time will FF4 be enabled.

The third input pulse at time t_3 will set FF1 to its 0 state. Both $\bar{Q}$ outputs from FF1 and FF2 are now logic 1 and the 8-4-2-1 output is 0011 (decimal 3). FF2 will not change states because the Q output of FF1 was a positive-going transition (logic 1 to logic 0).

The fourth input pulse at time t_4 sets FF1 to its 0 state. The Q output of FF1 sets FF2 to its 0 state. The negative-going pulse from the Q output of FF2 sets FF3 to its 0 state. The $\bar{Q}$ output of FF3 is now logic 1 and the 8-4-2-1 output is 0100 (decimal 4). Since $\bar{Q}$ of FF2 is logic 0 and Q of FF3 is logic 1, the C input to FF4 is still inhibited by the NOR gates.

The fifth input pulse at t_5 sets FF1 to its 1 state. The $\bar{Q}$ outputs of FF1 and FF3 are logic 1 and the 8-4-2-1 output is 0101 (decimal 5).

The sixth input pulse at t_6 sets FF1 to its 1 state. The $\bar{Q}$ output of FF1 is now logic 0. The Q output of FF1 sets FF2 to its 0 state. The $\bar{Q}$ output of FF2 is now logic 1 and the 8-4-2-1 output is 0110 (decimal 6). Now that the $\bar{Q}$ outputs of FF2 and FF3 are both logic 1, FF4 is enabled, but will not change states until the Q output of FF1 produces a negative-going pulse.

The seventh input pulse at t_7 sets FF1 to its 0 state. The $\bar{Q}$ outputs from FF1, FF2, and FF3 are all logic 1 and the 8-4-2-1 output is 0111 (decimal 7).

The eighth input pulse at t_8 sets FF1 to its 1 state. The Q output of FF1 sets FF2 to its 1 state and FF4 to its 0 state. The $\bar{Q}$ output of FF2 sets FF3 to its 1 state. The $\bar{Q}$ output of FF4 is now logic 1 and the 8-4-2-1 output is 1000 (decimal 8).

The ninth input pulse at t_9 sets FF1 to its 0 state. The $\bar{Q}$ output from FF1 and FF4 are both logic 1 and the 8-4-2-1 output is 1001 (decimal 9).

The tenth input pulse at t_{10} sets FF1 to its 1 state. Since the C input of FF2 is now inhibited by the Q output of FF4 it cannot change states. The C input to FF4 is also inhibited by the NOR gates. This inhibit level prevents setting FF4 to its 0 state, but does not inhibit setting it to its 1 state (reset). Thus, the $\bar{Q}$ output of FF1 sets FF4 to its 1 state. The $\bar{Q}$ output of FF4 supplies a carry pulse to the next decade counter. The $\bar{Q}$ outputs from all the flip-flops are now logic 0 and the 8-4-2-1 output is 0000.

Each of the remaining DCU's is contained in an individual integrated circuit. Operation of these decade counters is similar to that of the input DCU with the exception of the input trigger signal. Instead of being triggered by a negative-going signal, these DCU's are triggered by a positive-going signal. The 8-4-2-1 output and carry signals are coupled to the buffer/storage units and the next decade counter, respectively.

This decade counter will continue to count the input signal until a timing signal is applied to the S and C inputs of FF1 to inhibit the counter. A reset signal is also applied to the Cd inputs resetting each flip-flop to its 1 state.

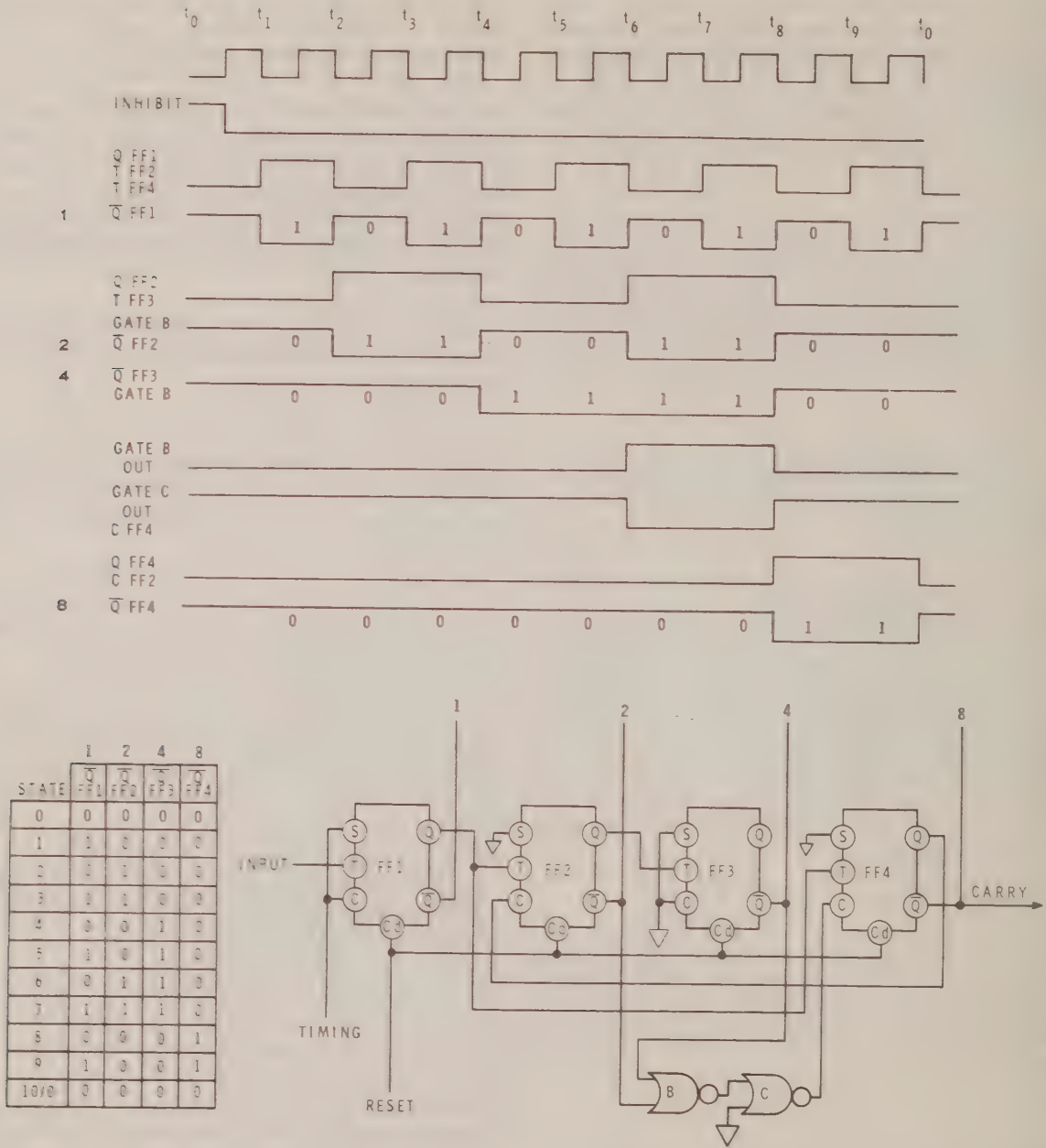


Figure 14

BUFFER/STORAGE UNITS

The buffer/storage units accept and store the binary-coded 8-4-2-1 outputs from the DCU's. Each time a transfer pulse is applied, the buffer/storage stages accept a new count from the DCU's and holds this count until the next transfer pulse. The transfer pulse originates in the clock circuit and after appropriate shaping and gating is applied to each buffer/storage unit.

Figure 15 illustrates a simplified block diagram of a buffer/storage unit. Only during the time a transfer signal is present at the transfer input are the flip-flops enabled. At this time the flip-flops will accept and store the 8-4-2-1 input. The 8-4-2-1 output of the buffer/storage units are applied to the decoder-drivers.

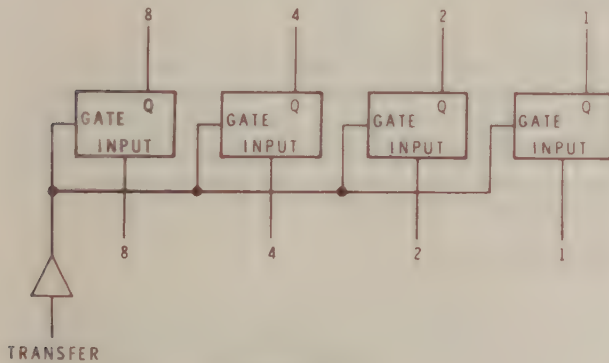


Figure 15

DECODER-DRIVERS

A matrix decodes the 8-4-2-1 input into decimal form. This decimal information then drives the appropriate cathodes of the display tubes. The numerals in the display tubes glow when the cathodes are grounded.

OVERRANGE

Inverter transistor Q3, integrated circuit IC26, and driver transistor Q4 form the overrange circuit. Flip-flops FFA and FFB of IC26 are connected as a latching circuit that turns on the "OVER" lamp any time a carry is produced by decade counter IC20.

Assume both flip-flops to be reset. The Q output of FFA places a logic 0 back to the S input of FFA. Since the C input to FFA is grounded, it is also at a logic 0 level. With a logic 0 at the S and C inputs, FFA will change states when a negative-going trigger signal is applied to the T input.

The S and C inputs of FFB, which are coupled to the Q and $\bar{Q}$ outputs of FFA, respectively, will follow the logic levels present at the Q and $\bar{Q}$ outputs of FFA. When FFA is reset (Q = logic 1), as is the case when the most significant DCU does not produce a carry pulse, the S input to FFB is logic 1 and the C input is logic 0. Under these conditions, a toggle signal applied to the T input will cause FFB to change to, or remain in, its 1 state. Since the Q output of FFB is then logic 1 (high), transistor Q4 is turned on; thus, turning the Overrange lamp on.

A positive-going carry signal, produced by the most significant DCU, is inverted by transistor Q3. The carry signal is now negative-going and serves as a toggle signal to FFA, setting it to its 0 state. Output Q of FFA is fed back to the S input holding it at logic 0. A logic 0 at the S input and a logic 1 at the C input inhibits FFA from changing from its 0 state when additional toggle signals are applied to the T input. FFA is thus latched in its 0 state and can only be reset by applying a reset pulse to the Cd input.

With FFA in its 0 state, the S input of FFB is logic 0 and the C input is logic 1. These inputs will cause FFB to change to and remain in its 0 state when the next transfer pulse is applied to the T Input. Output Q of FFB then goes to logic 1 (low), turning off transistor Q4 and the Overrange lamp.

The next reset pulse will reset FFA to its 1 state. If a carry signal is again produced by the most significant DCU, FFA will set to its 0 state. FFB, however, will not change states and the Overrange lamp will remain lit. If a carry pulse is not generated, FFA will remain in its 1 state. The S input of FFB will now be logic 1 and the C input will be logic 1. The next transfer pulse will cause FFB to reset to its 1 state. Output Q of FFB, which is now logic 0, turns transistor Q4 and the Overrange lamp on.

CLOCK

Gates A and D of IC25 are connected in a cross-coupled multivibrator configuration. Basically, a free-running oscillator, the output frequency is controlled by the crystal. Resistors R9 and R11 provide the bias for both gates as well as being part of the oscillator time constants. Trimmer capacitor C7 is adjusted so the oscillator frequency is exactly 1 MHz. The square-wave output drives the following DCU's.

The Divider chain consists of six cascaded DCU's. Since the binary-coded 8-4-2-1 outputs are not used, only the carry output is shown.

Three output signals, 1 kHz from IC3, 10 Hz from IC5, and 1 Hz from IC6, are used for timing purposes. A 10 kHz output from IC2 is coupled to the test point for use during calibration to adjust the input sensitivity of the Counter.

GATE

The Hz position of the range switch couples a 1 second (1 Hz) signal from the clock and divider chain to inverter B. Inverter B changes the clock signal into a negative-going pulse suitable for toggling FFB of IC22. FFB will now change states at a 1 Hz rate or once every second. The $\bar{Q}$ output or gate signal is used to both enable and inhibit input flip-flop IC21. During the one second interval when the input flip-flop is enabled, the input signal is counted. The one second interval the input flip-flop is inhibited, the accumulated count is transferred, stored, displayed, and reset. Thus, the Hz position of the range switch requires two seconds to complete its cycle.

The kHz position of the range switch couples a 1 millisecond (1 kHz) signal from the clock and divider chain to inverter B. FFB of IC22 will change states at a 1 kHz rate or once every 1 millisecond. The input signal is counted for 1 millisecond periods in the kHz position of the range switch.

TRANSFER

Figure 16 shows how two inverters can be connected to form a NAND gate. The truth table for this particular NAND gate, often called the "wired NAND" gate, is the same as the NAND gate previously explained.

Inverters C and D form a NAND gate that produces an output pulse at the same time flip-flop IC21 is inhibited. This output pulse is differentiated by capacitor C12 and resistor R16 before it is applied to inverter A in the Hz position of the Range switch. The output of this inverter forms the transfer pulse that transfers and stores the count, present in the DCU's, in the buffer/storage units. The kHz

position of the range couples a .1s (10 Hz) signal from the clock and divider chain to inverter A. Thus, in the kHz position of the Range switch, the transfer pulse is generated in the clock divider chain circuit.

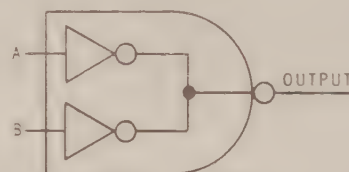


Figure 16

The output of the NAND gate (inverters C and D) is also applied to the Cd input of FFB of IC22 for synchronization.

RESET

The NAND gate output is also differentiated by C14 and R17 and then delayed slightly by R18 and C15 before it reaches transistor Q2. The reset pulse generated by Q2 resets all the DCU's after the 8-4-2-1 has been transferred to the buffer/storage units and before the input flip-flop (IC21) is gated on by the gate signal.

POWER SUPPLY

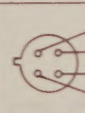
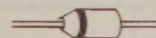
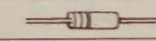
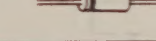
The dual-primary transformer T101 can be wired to operate from either 120 Vac or 240 Vac. Two secondary output windings furnish the ac voltage for the +3.5-volt and the +170-volt power supplies.

Diodes D1 and D2 form a full-wave rectifier for the 3.5-volt regulator. Transistors Q5 and Q6 form a constant current source to maintain a constant current through zener diode ZD2 over a wide voltage range. The bias of Q7 is held constant by ZD2. Since the bias of Q8 is held constant by Q7, the output voltage will remain constant. An increase in the dc voltage into the regulator will cause the emitter voltages of Q8 and Q7 to try to increase. Increasing the emitter voltage will decrease the forward bias, maintaining the output voltage at +3.5 volts. Capacitor C16 and C17 provide filtering for the 3.5-volt supply.

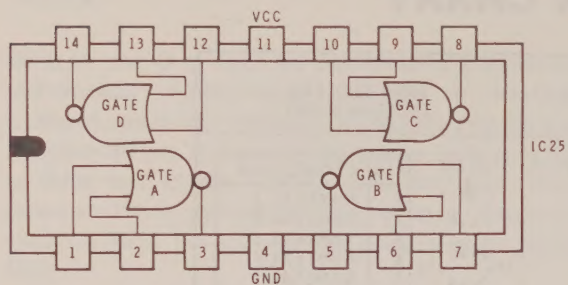
Diode D3 forms a half-wave rectifier for the +170-volt power supply. Capacitor C18 provides filtering for the +170-volt supply.

Resistor R34 provides current limiting for zener diode ZD1 which regulates the output at 36 volts. Capacitor C19 provides filtering.

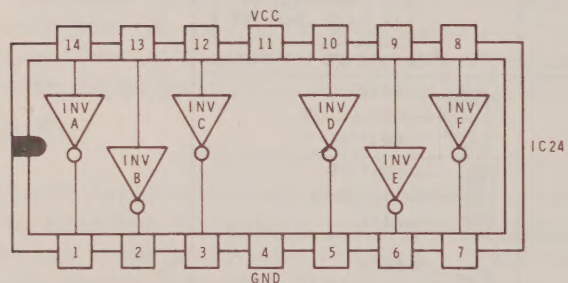
IDENTIFICATION CHART

COMPONENT	HEATH PART NUMBER	MAY BE REPAIRED WITH	BASE DIAGRAM (BOTTOM VIEW)																														
V1, V2, V3, V4, V5	411-264	NATIONAL ELECTRONICS NL905S OR BURROUGHS B-5859S	VIEW ↓ 7..6 8..5 14..4 9..4 10..3 11..2 12..1 <table><tr><th>PIN</th><th>CONNECTION</th></tr><tr><td>1</td><td>NUMERAL 1</td></tr><tr><td>2</td><td>NUMERAL 2</td></tr><tr><td>3</td><td>NUMERAL 3</td></tr><tr><td>4</td><td>NUMERAL 4</td></tr><tr><td>5</td><td>NUMERAL 5</td></tr><tr><td>6</td><td>NUMERAL 6</td></tr><tr><td>7*</td><td>ANODE</td></tr><tr><td>8</td><td>NUMERAL 7</td></tr><tr><td>9</td><td>NUMERAL 8</td></tr><tr><td>10*</td><td>ANODE</td></tr><tr><td>11</td><td>NUMERAL 9</td></tr><tr><td>12</td><td>NUMERAL 0</td></tr><tr><td>13</td><td>RT. DEC. PT.</td></tr><tr><td>14</td><td>LFT. DEC. PT.</td></tr></table> * CONNECTED INTERNALLY	PIN	CONNECTION	1	NUMERAL 1	2	NUMERAL 2	3	NUMERAL 3	4	NUMERAL 4	5	NUMERAL 5	6	NUMERAL 6	7*	ANODE	8	NUMERAL 7	9	NUMERAL 8	10*	ANODE	11	NUMERAL 9	12	NUMERAL 0	13	RT. DEC. PT.	14	LFT. DEC. PT.
PIN	CONNECTION																																
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12	NUMERAL 0																																
13	RT. DEC. PT.																																
14	LFT. DEC. PT.																																
Q2, Q5, Q6	417-201	X29A829																															
Q8	417-175	TA2911																															
Q3, Q7	417-118	2N3393	 																														
Q4	417-173	2N2509	  																														
Q1	417-240	RCA 40673																															
D1, D2, D3	57-27	1N2071																															
D4	56-26	1N191																															
ZD1	56-55	VR-36, 36VOLT, 4mA ZENER																															
ZD2	56-59	1N750A 4.7VOLT, 20mA ZENER																															

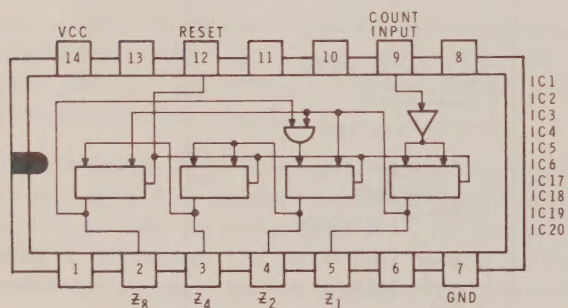
TOP VIEW



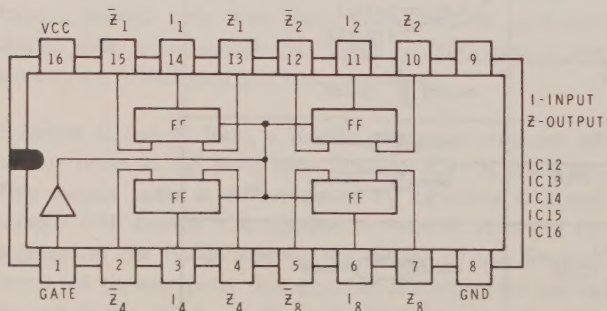
MC724P QUADRUPLE 2-INPUT
NAND/NOR GATE
#443-8



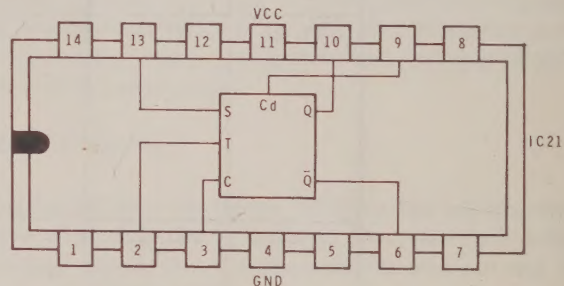
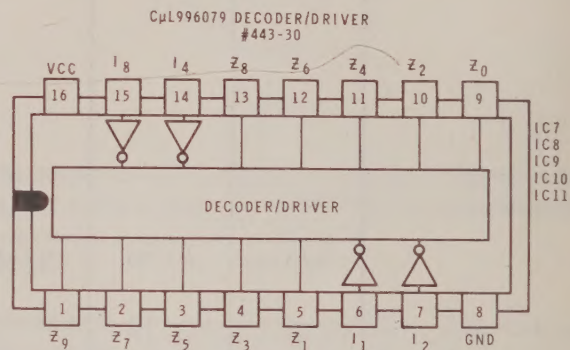
MC789P (Selected 15MHz)
HEX INVERTER
#443-14



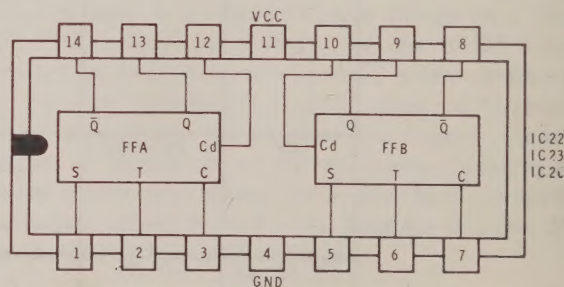
CμL995879 DECADE COUNTER
#443-28



CμL995979 BUFFER-STORAGE
ELEMENT
#443-29



MC726P (Selected 15MHz) single
J-K FLIP-FLOP
#443-31



MC790P (Selected 8MHz) DUAL
J-K FLIP-FLOP
#443-32

MP MASTER



MA22999